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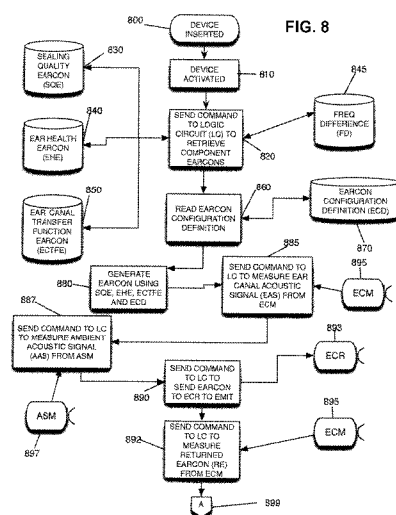
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(54) Title: MUSICAL, DIAGNOSTIC AND OPERATIONAL EARCON



(57) Abstract: At least one exemplary is directed to a method of acoustic communication comprising: emitting an earcon, where the earcon has at least one embedded portion, where the at least one embedded portion includes at least one of a sealing quality earcon, a ear health earcon, and an ear canal transfer function earcon; measuring a return earcon; breaking the return earcon into return portions, where the return portions are broken into at least one of a sealing quality portion, an ear health portion, and an ear canal transfer function portion; and comparing the return portions with reference portion values; and sending a notification signal if there are differences between the return portions and the reference portion values outside of a threshold value.

MUSICAL, DIAGNOSTIC AND OPERATIONAL EARCON

FIELD OF THE INVENTION

[0001] The present invention is related to communicating and obtaining information acoustically, and in particular, though not exclusively, communicating and obtaining acoustically diagnostic and operational status.

BACKGROUND OF THE INVENTION

[0002] Information can be communicated to a user via many possible methods. For example visually or acoustically. Conventional systems lack an acoustic signal that performs health diagnostics of a user and a device, and supplies operational information acoustically.

[0003] For example in earpieces (e.g., earbuds, ear terminals, headphones, hearing aids, and other devices worn by a user to provide acoustical energy into the ear canal) acoustical properties can vary depending upon the earpiece seal (acoustic seal) in the ear canal. Imperfections in the acoustic seal in the ear canal can cause ambient sound to leak into the ear canal, and thereby increase the Sound Pressure Level (SPL) in the ear canal, and increase SPL Dose. If the seal is compromised, the low frequency SPL (usually <500 Hz) is decreased (the SPL is compared with a previously measured low frequency SPL where the seal was intact).

[0004] Otoacoustic emissions (OAEs) are low-level acoustic signals that emanate from the cochlea and can be detected by a microphone in the ear canal. Distortion product and Transient Evoked Otoacoustic Emissions (TEOAEs) are the most studied. These OAE signals are generated as a byproduct of the active mechanisms associated with the processes of hearing. OAEs can be elicited in the vast majority of ears with normal hearing sensitivity, and are absent in ears with

greater than a mild degree of cochlear hearing loss. Thus, currently OAEs are thus thought to reflect normal cochlear function.

[0005] OAEs have been used for screening for normal hearing function in difficult-to-test populations. For example, universal newborn hearing screening programs very often make use of OAEs to determine if a newborn's hearing is likely to be normal, or if they need a more thorough hearing evaluation. In recent years, studies have shown that OAEs change in response to insults (e.g., damage) to the cochlear mechanism from noise and from ototoxic medications, prior to changes in the pure-tone audiogram. An additive effect of reduction of OAEs was observed in groups exposed to recreational and/or occupational noise.

[0006] OAEs have not found their way into occupational hearing conservation programs, as the OAE has yet to successfully predict absolute hearing threshold, and due to inter-subject variability. However, it has been shown that OAEs are highly repeatable within the same subject over time.

SUMMARY OF THE INVENTION

[0007] In a first embodiment, a method for communicating earpiece status can include emitting an earcon, measuring a return earcon, breaking the return earcon into return portions, comparing the return portions with reference portion values, and sending a notification signal if there are differences between the return portions and the reference portion values outside of a threshold value. The earcon can include at least one embedded portion, where the at least one embedded portion includes at least one of a sealing quality earcon, a ear health earcon, and an ear canal transfer function earcon. The return portions can be broken into at least one of a sealing quality portion, an ear health portion, and an ear canal transfer function portion.

[0008] The method can include monitoring ear canal sound pressure levels using an Ear Canal Microphone, monitoring for sound leakage from an Ear Canal Receiver (ECR) loudspeaker using an Ambient Sound Microphone, and detecting sound components correlated with earcon signals radiated by the ECR. The earcon can be embedded within a musical signal in accordance with temporal masking principles to minimize perception of the earcon. The Earcon can include embedded TEOAE test stimuli based on principles of temporal backward masking to reduce a perceptual loudness of the TEOAE test stimulus. An audiogram test can be invoked if an earcon measurement indicates abnormal user auditory health.

[0009] The earcon can include portions for an initial time segment for background noise assessment, a swept sine wave segment for measuring an Ear Canal Transfer Function (ECTF), a segment of clicks to measure otoacoustic emission acoustic responses, and a section of alternating tones for measuring ear seal integrity.

[0010] In a second embodiment a method for indicating operational status of an earpiece can include the steps of reproducing operational audio content with an Ear Canal Receiver (ECR) housed in the earpiece, analyzing signals from an ear canal microphone (ECM) of the earpiece responsive to the reproducing, generating at least one acoustic indication features from the signals analyzed, outputting an indicator representing the state of the at least one acoustic indication features, and detecting an operational status of the earpiece by in view of the indicator. The acoustic indication feature can include one among an ear health profile, an earphone device acoustical fitting status, and an mear seal integrity. The related operational audio content can be a music signal with embedded otoacoustic emission acoustic test signals. It can comprise at least one among a remaining battery power, a remaining processing power, and a remaining memory storage space for the earpiece or a paired communication device.

[0011] The method can include estimating a background noise level within the ear canal during the step of analyzing and estimate, and suppressing a contribution of the background noise level from the acoustic indication feature. The method can also include scheduling the reproducing of the operational audio content upon detecting an insertion of the earpiece in an ear canal, and intermittently performing an ear seal test to monitor the integrity of the insertion. The method can include monitoring changes in sound pressure level across a frequency spectrum with respect to a predetermined ear sealing profile to determine if a sealing of the earpiece is compromised.

[0012] The operational audio content can be an earcon with temporal portions devoted to various diagnostics and operational indications. The earcon can include a temporal portion for background noise assessment. For instance, the earcon can include a swept sine wave segment for measuring an Ear Canal Transfer Function (ECTF); the earcon can include a section of clicks to measure otoacoustic emission acoustic responses; and, the earcon can include a section of alternating tones for measuring ear seal integrity.

[0013] In a third embodiment, a method for determining an operational status of an earpiece can include the steps of generating and emitting an earcon to an ear canal of a user wearing an inserted earpiece, analyzing signals measured at an ear canal microphone (ECM) of the earpiece within the ear canal responsive to the earcon, and determining the operational status in view of the signals analyzed that identifies a remaining battery power. The step of analyzing can identify at least one among a Sealing Quality Earcon (SQE), an Ear Health Earcon (EHE), and an Ear Canal Transfer Function (ECTF). The step of analyzing can determine a Frequency Difference (FD) portion between a musical score and the earcon.

[0014] The method can include measuring an ambient acoustic signal (AAS) and an ear canal acoustic signal (EAS) to validate that the earpiece is inserted

before proceeding with the step of generating and emitting the earcon. A noise reduction rating of the earpiece can also be measured for determining the operational status. The method can include temporally splitting the earcon into temporally separate and distinct portions. An analysis can be performed on the separate distinct portions to determine if differences with predetermined mapping of the separate and distinct portions are within respective tolerances. The tolerances can be frequency specific for the separate distinct portions.

[0015] The method can include outputting an indicator representing by generating a visual message on a portable communication device indicating the operational status of at least one acoustic indication feature, generating an email communication and sending it to the user to indicate the operational status of the at least one acoustic indication feature, generating an electronic communication and sending it to a database storage server. The operational status identifies at least one among a signal noise measurement function, an Ambient Sound Microphone (ASM) sensitivity, and an Ear Canal Receiver (ECR) sensitivity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Exemplary embodiments of present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0017] FIG. 1 is a pictorial diagram of an earpiece in accordance with an exemplary embodiment;

[0018] FIG. 2 is a block diagram of the earpiece in accordance with an exemplary embodiment;

[0019] FIG. 3 illustrates a serial type earcon where portions of the earcon are devoted toward various diagnostics and operational indication;

[0020] FIG. 4 illustrates at least one method of earcon generation and usage in accordance with at least one exemplary embodiment;

[0021] FIG. 5 illustrates at least one method of obtaining the noise reduction rating (NRR) of a device in accordance with at least one exemplary embodiment, which can be used to detect sealing quality;

[0022] FIG. 6 illustrates at least one method of obtaining an ear canal transfer function (ECTF) and comparing it to stored reference values, for example for identify of the wearer, in accordance with at least one exemplary embodiment;

[0023] FIG. 7 illustrates at least one method of obtaining an OAE in accordance with at least one exemplary embodiment;

[0024] FIG. 8 illustrates a method of generating and emitting an earcon in accordance with at least one exemplary embodiment;

[0025] FIG. 9 illustrates at least one method of receiving a returned earcon and analyzing its components against reference values to determine, device and operator status (e.g., sealing quality (SQ), ECTF of the user, and ear health (EH) of the user) in accordance with at least one exemplary embodiment;

[0026] Figures 10A-10G illustrate various types of earcons in accordance with at least one exemplary embodiment; and

[0027] Figures 11A-11E illustrate various spectral signatures of various operational earcons, where the temporal length has not been specified, in accordance with at least one exemplary embodiment.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS OF THE PRESENT INVENTION

[0028] The following description of exemplary embodiment(s) is merely illustrative in nature and is in no way intended to limit the invention, its application, or uses.

[0029] Exemplary embodiments are directed to or can be operatively used on various wired or wireless earpieces devices (e.g., earbuds, hearing aid, headphones, ear terminal, behind the ear devices or other acoustic devices as known by one of ordinary skill, and equivalents).

[0030] Processes, techniques, apparatus, and materials as known by one of ordinary skill in the art may not be discussed in detail but are intended to be part of the enabling description where appropriate. For example specific computer code may not be listed for achieving each of the steps discussed, however one of ordinary skill would be able, without undue experimentation, to write such code given the enabling disclosure herein. Such code is intended to fall within the scope of at least one exemplary embodiment.

[0031] Additionally exemplary embodiments are not limited to earpieces, for example some functionality can be implemented on other systems with speakers and/or microphones for example computer systems, PDAs, Blackberrys, cell and mobile phones, and any other device that emits or measures acoustic energy. Additionally, exemplary embodiments can be used with digital and non-digital acoustic systems. Additionally various receivers and microphones can be used, for example MEMS transducers, diaphragm transducers, for examples Knowle's FG and EG series transducers.

[0032] Notice that similar reference numerals and letters refer to similar items in the following figures, and thus once an item is defined in one figure, it may not be discussed or further defined in the following figures.

[0033] At least one exemplary embodiment is directed to a method of using earcons as a means for generating acoustical indication and for simultaneously informing the user of operational status of a device comprising the steps of: detecting an operational status of a device matching the detected operational status with a related operational audio content; reproducing the related operational audio content

with either or both an Ear Canal Loudspeaker and/or Ambient Sound Microphone housed in at least one earphone device; Analyzing the signals from an ear canal microphone (ECM) and /or ambient sound microphone with an audio signal analysis system and generating at least one acoustic indication features: an ear health profile; an earphone device acoustical fitting status; an earphone device electroacoustic operational status; and a background noise level estimate; and outputting an indicator representing the state of the at least one acoustic indication features.

[0034] In at least one exemplary embodiment the operational status includes at least one of the following information: remaining battery power of at least one of the following devices: an earphone or earpiece device; a portable communication device such as a mobile phone; and a portable media player (PMP); remaining memory storage space of at least one of the following devices: an earphone or earpiece device; a portable communication device such as a mobile phone; and a portable media player (PMP); a signal noise measurement function; and an ear-seal test signal. Where portions of the test signal can only be heard at the same level as other portions of the test signal when the ear seal of the earphone (i.e. earpiece) device is substantially correct-fitting (e.g. a 50 Hz tone alternating with a 150 Hz tone).

[0035] At least one exemplary embodiment of the invention is directed to an earpiece for background noise mitigation. Reference is made to **FIG. 1** in which an earpiece device, generally indicated as earpiece 100, is constructed in accordance with at least one exemplary embodiment. As illustrated, earpiece 100 depicts an electro-acoustical assembly 113 for an in-the-ear acoustic assembly, as it would typically be placed in the ear canal 131 of a user 135. The earpiece 100 can be an in the ear earpiece, behind the ear earpiece, receiver in the ear, open-fit device, or any other suitable earpiece type. The earpiece 100 can be partially or fully

occluded in the ear canal, and is suitable for use with users having healthy or abnormal auditory functioning.

[0036] Earpiece 100 includes an Ambient Sound Microphone (ASM) 111 to capture ambient sound, an Ear Canal Receiver (ECR) 125 to deliver audio to an ear canal 131, and an Ear Canal Microphone (ECM) 123 to capture internal sounds within the ear canal and also assess a sound exposure level within the ear canal. The earpiece 100 can partially or fully occlude the ear canal 131 to provide various degrees of acoustic isolation. The assembly is designed to be inserted into the users ear canal 131, and to form an acoustic seal with the walls of the ear canal at a location 127 between the entrance to the ear canal and the tympanic membrane (or ear drum) 133. Such a seal is typically achieved by means of a soft and compliant housing of assembly 113. Such a seal is pertinent to the performance of the system in that it creates a closed cavity 131 of approximately 5cc between the in-ear assembly 113 and the tympanic membrane 133. As a result of this seal, the ECR (speaker) 125 is able to generate a full range bass response when reproducing sounds for the user. This seal also serves to significantly reduce the sound pressure level at the user's eardrum resulting from the sound field at the entrance to the ear canal. This seal is also the basis for the sound isolating performance of the electro-acoustic assembly.

[0037] Located adjacent to the ECR 125, is the ECM 123, which is acoustically coupled to the (closed) ear canal cavity 131. One of its functions is that of measuring the sound pressure level in the ear canal cavity 131 as a part of testing the hearing acuity of the user as well as confirming the integrity of the acoustic seal and the working condition of itself and the ECR. The ECM 123 can also be used for capturing voice that is resonant within the ear canal when the user is speaking to permit voice communication.

[0038] The ASM 111 is housed in an ear seal 113 and monitors sound pressure at the entrance to the occluded or partially occluded ear canal. The ASM 111 can also be used to capture the user's voice externally for permitting voice communication. All transducers shown can receive or transmit audio signals to a processor 121 that undertakes audio signal processing and provides a transceiver for audio or voice via the wired or wireless communication path 119.

[0039] The earpiece 100 can actively monitor a sound pressure level both inside and outside an ear canal and enhance spatial and timbral sound quality while maintaining supervision to ensure safe sound reproduction levels. The earpiece 100 in various embodiments can conduct listening tests, filter sounds in the environment, monitor warning sounds in the environment, present notification based on identified warning sounds, maintain constant audio content to ambient sound levels, and filter sound in accordance with a Personalized Hearing Level (PHL).

[0040] At least one exemplary embodiment includes a method to report the operational status of the following parameters of the earpiece 100: remaining battery life (e.g. a high-pitch tone indicates high remaining battery life); remaining non-volatile memory for storage of audio content signals; degree to which an earphone device is correctly fitted. Furthermore, environmental and personal information can be presented in the earcon: personal sound level exposure and current background noise level.

[0041] Referring to **FIG. 2**, a block diagram of the earpiece 100 in accordance with an exemplary embodiment is shown. As illustrated, the earpiece 100 can include a processor 206 operatively coupled to the ASM 111, ECR 125, and ECM 123 via one or more Analog to Digital Converters (ADC) 202 and Digital to Analog Converters (DAC) 203. The processor 206 can measure ambient sounds in the environment received at the ASM 111 and internal sounds captured at the ECM 130.

Ambient sounds correspond to sounds within the environment such as the sound of traffic noise, street noise, conversation babble, or any other acoustic sound.

[0042] Ambient sounds measured by the ASM 111 can also correspond to industrial sounds present in an industrial setting, such as, factory noise, lifting vehicles, automobiles, and robots. The processor 206 can monitor the ambient sound captured by the ASM 110 for sounds in the environment, such as an abrupt high energy sound corresponding to an on-set of a warning sound (e.g., bell, emergency vehicle, security system, etc.), siren (e.g., police car, ambulance, etc.) , voice (e.g., "help", "stop", "police", etc.), or specific noise type (e.g., breaking glass, gunshot, etc.).

[0043] Internal sounds measured by the ECM 123 can correspond to sounds contained within the ear canal 131 such as spoken voice or audio content delivered by way of the ECR 120. The internal sounds can include residual background noise related to ambient sounds in the environment; for example, high level sounds that leak around the ear seal 127 and enter the ear canal 131. The processor 206 can monitor internal sounds captured by the ECM 123 and analyze the internal sounds. The processor 206 can also adjust a mixing between the ambient sound signals measured at the ASM 111 and the internal sound signals measured at the ECM 123, for example, responsive to assessing ambient background noise conditions.

[0044] The processor 206 can utilize computing technologies such as a microprocessor, Application Specific Integrated Chip (ASIC), and/or digital signal processor (DSP) with associated storage memory 208 such as a Flash, ROM, RAM, SRAM, DRAM or other like technologies for controlling operations of the earpiece device 100. The memory 208 can store program instructions for execution on the processor 206 as well as captured audio processing data.

[0045] The memory 208 can also store program instructions for execution on the processor 206. The memory 208 can be off-chip and external to the processor 208, and include a data buffer to temporarily capture the ambient sound and the internal sound, and a storage memory to save from the data buffer the recent portion of the history in a compressed format responsive to a directive by the processor. The data buffer can be a circular buffer that temporarily stores audio sound at a current time point to a previous time point. It should also be noted that the data buffer can in one configuration reside on the processor 206 to provide high speed data access. The storage memory can be non-volatile memory such as SRAM to store captured or compressed audio data.

[0046] The memory 208 can be a machine-readable medium. The term "machine-readable medium" should be taken to include a single medium or multiple media (e.g., a centralized or distributed, and/or associated caches and external memory) that store the one or more sets of instructions. The term "machine-readable medium" shall also be taken to include any medium that is capable of storing, encoding or carrying a set of instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the present disclosure.

[0047] The term "machine-readable medium" shall accordingly be taken to include, but not be limited to: solid-state memories such as a memory card or other package that houses one or more read-only (non-volatile) memories, random access memories, or other re-writable (volatile) memories; and/or magneto-optical or optical medium; and carrier wave signals such as a signal embodying computer instructions in a transmission medium. Accordingly, the disclosure is considered to include any one or more of a machine-readable medium or a distribution medium, as listed herein and including art-recognized equivalents and successor media, in which the software implementations herein are stored.

[0048] The earpiece 100 can include an audio interface 212 operatively coupled to the processor 206 to receive audio content, for example from a media player or cell phone, and deliver the audio content to the processor 206. The processor 206 responsive to detecting ambient sounds can adjust the audio content and pass the ambient sounds directly to the ear canal. For instance, the processor 206 can lower a volume of the audio content played out the ECR 125 responsive to detecting an acute sound for transmitting the ambient sound to the ear canal. The processor 206 can also actively monitor the sound exposure level inside the ear canal via the ECM 123 and adjust the audio content to within a safe and subjectively optimized listening level range.

[0049] The earpiece 100 can further include a transceiver 204 that can support singly or in combination any number of wireless access technologies including without limitation Bluetooth™, Wireless Fidelity (WiFi), Worldwide Interoperability for Microwave Access (WiMAX), and/or other short or long range communication protocols. The transceiver 204 can also provide support for dynamic downloading over-the-air to the earpiece 100. It should be noted also that next generation access technologies can also be applied to the present disclosure.

[0050] The power supply 210 can utilize common power management technologies such as replaceable batteries, supply regulation technologies, and charging system technologies for supplying energy to the components of the earpiece 100 and to facilitate portable applications. A motor (not shown) can be a single supply motor driver coupled to the power supply 210 to improve sensory input via haptic vibration. As an example, the processor 206 can direct the motor to vibrate responsive to an action, such as a detection of a warning sound or an incoming voice call.

[0051] The earpiece 100 can further represent a single operational device or a family of devices configured in a master-slave arrangement, for example, a

mobile device and an earpiece. In the latter embodiment, the components of the earpiece 100 can be reused in different form factors for the master and slave devices.

[0052] FIG. 3 illustrates a serial type earcon where portions of the earcon are devoted toward various diagnostics and operational indication. Figure 3 illustrates a non-limiting example of an Earcon, where the time span is shown at 15 seconds although the temporal extent of the Earcon is not limited. For example section A= initial introduction (no sound- for measuring Background Noise Level), section B= Swept sine wave from 50 Hz-15 kHz (exponential sweep) to measure ECTF, section C=15 repeated transient clicks to measure TEOAE (clicks can be band-pass-filtered for musical pitch), section D=Alternating 50 Hz and 150 Hz tone to measure ear seal (i.e. the user should hear the two tones at the same loudness if the seal is correct).

[0053] At least one exemplary embodiment includes earcons' embedded in musical scores, where the earcons' detection can be minimized, for example the time of event is chosen in accordance with temporal masking principles whereby a target sound is embedded in a masking noise. Where in this sense "masking" refers to the amount (or process) by which the threshold of audibility for a target sound is raised by the presence of another masking sound. Forward masking occurs when the masking sound precedes the target sound. In at least one exemplary embodiment the earcon test signal is intended to be played as part of a musical composition, e.g. using MLS test signals or transient clicks (with the click stimulus, a transient-evoked OAE can be measured).

[0054] At least one exemplary embodiment is directed to an auditory operational indicator for example a swept sine wave from, for example, 100Hz-15 kHz, and then another single pulse to indicate battery life (e.g. 50% battery gives a pitch of approx 4 kHz where a log-frequency scale can be used). Additionally the initial earcon can have an initial device operational status auditory indicator attached

to the earcon, such as the swept sine wave discussed above. Briefly, FIGS 11A-11E, indicate further examples of operational earcons that can be emitted to indicate to a user operational environment and status (e.g., battery life, incoming call, incoming call name, incoming e-mail, feature on, feature off, wireless connection complete, volume, and any other operational status and environmental indicators one of ordinary skill can think of that can be associated with an earpiece, PDA, cell phone, computer, biometric indicator information., and ambient environment indication (e.g., temp, humidity)).

[0055] Figure 4 illustrates at least one method of earcon generation and usage in accordance with at least one exemplary embodiment. The method can start at step 401. At step 402 a mobile device activation can be checked. If the mobile device is not ready it continues in a wait state at state 401. If the device is activated, an insertion check is performed at step 403. If the earphone (e.g., earpiece 100) is not ready, the method 400 can continue until the earphone is inserted. When the earphone is detected as being inserted, an earcon can be fetched at step 404 from a memory storage 405. The earcon can also be generated by an algorithm as shown in step 406.

[0056] At step 408, the earcon can be reproduced with the loudspeakers such as the ECR 125 as shown at filtering step 409 and sound reproduction step 410. Alternatively, the earcon can be filtered for ambient sound generation at step 411 and reproduced by way of the ASM 111 at step 412.

[0057] During earcon reproduction, the method can include recording the microphone signals as shown in step 407. The recordings captured from either the ASM loudspeaker 111 (step 415) or the ECM 123 (step 416) can be stored in memory storage at step 414. The method can continue to record the response to the earcon until the earcon has finished playing. The response can be a residual sound of the earcon within the ear canal, or an otoacoustic emission response.

[0058] When the earcon has finished playing, the earpiece (e.g., processor 206) can analyze the recorded microphone signals at step 418. The earpiece can reference one or more predetermined measurements to determine if the response is within a tolerance. The recorded signals and corresponding analysis can be saved to memory storage at step 420. The analysis can be emailed to the user, or a service provider, at step 421, and/or logged to a database at step 422. Alternatively, other forms of feedback can be provided to the user at step 423, such as a voice message or other text indication.

[0059] Figure 5 illustrates at least one method of obtaining the noise reduction rating (NRR) of a device in accordance with at least one exemplary embodiment, which can be used to detect sealing quality. In at least one exemplary embodiment the earphone device acoustical fitting status includes at least one of the following: the Ear Canal Transfer function (ECTF), an Ear Seal measurement status. the frequency-dependant effective NRR of an inserted earpiece.

[0060] The method 500 can be performed in response to generating and reproducing an earcon such as that shown in FIG. 3, where different portions of the earcon are reproduced in a predetermined time sequence to permit various ear sealing, ear health, and integrity tests.

[0061] The method 500 can start in state 501. At step 502, the microphone buffer from the ASM 111 can be recorded. At step 503 an initial audio assessment can be made. During the initial portion of the earcon (see 300) where no sound is reproduced, the earpiece can estimate the background noise level at step 504 and generate a background noise estimate as shown in step 506. The earpiece 100 can also measure the ASM sensitivity as shown in step 505 when accounting for the background noise estimate.

[0062] At least one exemplary embodiment includes a method where the earphone device electroacoustic operational status includes at least one of the

following: a battery power measurement status; a remaining audio content storage memory status, a signal noise measurement function, an Ear Canal microphone (ECM) sensitivity function, an Ambient Sound microphone (ASM) sensitivity function, and an Ear Canal Receiver (ECR) sensitivity function.

[0063] At step 507, the processor (see 206 FIG. 2) of the earpiece can also the recorded microphone buffer from the ECM 123. Similarly, the earpiece can identify the initial preamble portion of the earcon (e.g., silence period, see 300 first portion FIG. 3) to validate that an earcon is being produced. At step 508, the ear canal background noise level can be estimated. The earpiece 100 can also measure the ECM sensitivity at shown in step 510 during the initial quiet portion, or estimation period.

[0064] At step 511, a background noise level difference between the ASM and the ECM is calculated. The processor 206 can subtract an average of the time domain responses, or a frequency domain average of the earcon responses. The difference can be expressed also in the log domain as a noise reduction rating (NRR) of the earpiece as shown in step 512.

[0065] If at step 513, the noise reduction rating is less than a threshold, for instance a known NRR of the earpiece 100 previously saved as a threshold in step 514, the earpiece 100 issues a warning to the user that the NRR is low. The earpiece can for instance send a text message to the user by way of a paired communication device, or generate audible voice that informs the user of the low NRR. The earpiece 100 can inform the user that the earpiece 100 may not be properly inserted, and that the user should reinsert or position the earpiece 100.

[0066] At least one exemplary embodiment includes outputting an indicator representing the at least one acoustic indication features by at least one of the following means: reproducing a sound icon with the Ear Canal Receiver, generating a visual message on a portable communication device indicating the

status of the at least one acoustic indication feature, generating an email communication and sending it to the user to indicate the status of the at least one acoustic indication feature, generating an electronic communication and sending it to a database storage server.

[0067] Figure 6 illustrates at least one method of obtaining an ear canal transfer function (ECTF) and comparing it to stored reference values, for example for identify of the wearer, in accordance with at least one exemplary embodiment. At step 601, the processor 206 can extract portions of the earcon response at the ECM 123 corresponding to a swept sine wave. Recall from FIG. 3 that the earcon can include portions for an initial time segment for background noise assessment, a swept sine wave segment for measuring an Ear Canal Transfer Function (ECTF), a segment of clicks to measure otoacoustic emission acoustic responses, and a section of alternating tones for measuring ear seal integrity.

[0068] At step 602, the earcon response can be de-convolved with an original sine sweep to determine the presence of the earcon portion. At step 604, the processor 206 can then compensate the ECM 123 and ECR 125 (also Ear Canal Loudspeaker) response based on a time domain 605 or frequency domain 606 Ear Canal Transfer Function (ECTF). At step 607 the processor 206 can compare the measured ECTF from the de-convolution, and a reference ECTF at step 608. If the difference between the ECTFs is greater than a threshold 612, the processor can inform the user that the ECTFs do not match, and suggest an ear seal leakage, as shown in step 610. The processor 206 can also disable the earpiece 100 at step 611 in the event the ECTF difference is unacceptable. If the difference is not greater than the threshold, the processor 206 can update the ear canal loudspeaker (e.g., ECR 125) with an inverse of the measured ECTF.

[0069] At least one exemplary embodiment of the present invention improves upon this seal-leak detection system by continuously monitoring ear canal

SPL using the Ear Canal Microphone, as well as monitoring for sound leakage from the Ear Canal Receiver (ECR) loudspeaker using the Ambient Sound Microphone to detect sound components correlated with that signal radiated by the ECR.

[0070] Figure 7 illustrates at least one method of obtaining an OAE in accordance with at least one exemplary embodiment. In at least one exemplary embodiment the ear health profile includes a user OtoAcoustic Emission (OAE) response (in the time-domain or frequency domain).

[0071] At step 701, the processor 206 can get a next portion of the ECM signal buffer containing the earcon response. Recall from FIG. 3 that the earcon can include temporal portions for background noise assessment, swept frequencies, and embedded otoacoustic emission signals. At step 702, the processor 206 can band-pass filter the ECM 123 signal portion for the OAE click. At step 703, the processor 206 can compensate for the ECM 123 and the ECR 125 (e.g., ECL) response to generate either or both a measured time domain TEOAE or a frequency domain TEOAE.

[0072] At step 706, the processor 206 can compare the measured TEOAE and a reference TEOAE previously saved at step 707 for a difference. If at step 708 the difference between the measured TEOAE and the reference TEOAE is greater than a predetermined threshold 709, the earpiece 206 can inform the user that the TEOAEs do not match. The earpiece 100 by way of a paired mobile device or audible voice generation can suggest to the user that the user's hearing may be compromised in view of the TEOAEs. The earpiece 100 can also email the results of the OAE test and associated details to the user, a service provider, or audiologist. The method 700 can also proceed to invoke an audiogram to further test the user's hearing acuity.

[0073] In at least one exemplary embodiment the Earcon can include embedded TEOAE test stimuli (i.e. a sound ID, like an icon for a product brand)

reproduced by the ECR in such a way that detection of the OAE test stimulus by the user is minimized. The embedding system can use principles of temporal masking (specifically, backward masking; Moore, 1997) to reduce the perceptual loudness of the test stimulus. Alternatively, the TEOAE test stimulus is presented as an earcon when the communication device is activated (or following a user activation command) in the form of a short musical fragment (e.g., 5-15 seconds). If the measurement made by the earcon indicates abnormal user auditory health, a threshold test or audiogram can be invoked manually or automatically, using the Ear Canal Receiver and Ear Canal Microphone to generate and monitor an ear canal SPL at a given frequency, and using the Ambient Sound Microphone to ensure that background noise levels are low enough to conduct the audiogram. Where a non-limiting example of “abnormal user auditory health” can refer to abnormal user auditory health = significant deviation (e.g. greater than 2 standard deviations from the mean) of a specific auditory health metric (such as the absolute norm difference between 2 OAE recording, measured from either a population of healthy adults of similar age, sex etc, or measured previously from the same user).

[0074] Figure 8 illustrates a method of generating and emitting an earcon in accordance with at least one exemplary embodiment. When a device is inserted 800, the device can be activated 810 or activated prior to insertion. After a period of time which can be a few seconds, upon power on, or after several minutes of power on to let a user have time to insert the device, a command can be sent to the LC, 820, requesting the LC to return at least one earcon portion, for example a sealing quality earcon (SQE) 830, an ear health earcon (EHE), 840, an ear canal transfer function earcon (ECTFE) 850, and a frequency difference portion (FD) between a final musical score and the selected earcons. Upon obtaining the earcon portions, an earcon configuration definition can be retrieved 860, which defines (e.g., serially, Figure 3; or super positional, e.g., Figures 10A-10G), how to combine the earcon

portions into a final earcon that can be emitted. Using the configuration definition an earcon can be generated 880.

[0075] Before emitting the earcon the ear canal acoustic signal (EAS) 885 and the ambient acoustic signal (AAS) can be measured and compared to check that the earpiece is inserted (both measured values are about equal, or whether the earpiece is in the process of sealing, e.g., obtaining an NRR value (see Figure 5)). Upon an adequate earcon emission environment (earpiece appears to be seated, and after the chosen wait time (e.g., 1 minute)), the earcon can be emitted 890 to the ECR 893, which emits the earcon. A command 892 is identically sent to the LC to start measuring input received from the ECM 895, and the LC send a returned earcon (RE).

[0076] Figure 9 illustrates at least one method of receiving a returned earcon and analyzing its components against reference values to determine, device and operator status (e.g., sealing quality (SQ), ECTF of the user, and ear health (EH) of the user) in accordance with at least one exemplary embodiment. The returned earcon (RE_ received from the LC, 910, can be broken into component earcon portions, 920, for example a sealing quality portion (SQP) 921, a ECTF portion (ECTFP) 923, and an ear health portion (EHP) 925. The SQP, ECTFP, and EHP can be compared to SQE, ECTFE, and EHE respectively within threshold values (for example, $\text{abs}(\text{SQP}-\text{SQE}) < 5 \text{ dB}$; ECTF difference no greater than 5%, and an ear health difference no greater than 3%, or other portion specific threshold values reasonably chosen), 930, 940, and 950. If the values are outside the threshold values notification signals can be sent (e.g., 935, 945, 955) which can include notification to the user (e.g., to reinsert the device), a tone (e.g., sealing quality loss), or a musical indicator (e.g., an alarm to indicate wrongful user). Once the measured portions are analyzed (e.g., compared with reference values, 930, 940, and 950) the device's other functions can be activated.

[0077] Figures 10A-10G illustrate various types of earcons in accordance with at least one exemplary embodiment. In accordance with the various earcons discussed, Figures 10A-10D illustrate combining an EHE, ECTFE, and SQE earcon into a minimal earcon 1. The minimal earcon 1 can be emitted and the returned earcon split into portions EHP, ECTFP, and SQP, where the differences between the values can be checked to see if they fall within certain tolerances (which can be frequency specific). Earcon 1 is illustrated in Figure 1E and can be emitted as is, or combined with or made part of a musical score earcon 2 (Figures 10F and 10G). If combined with (not shown) both are added creating a new musical-minimal earcon hybrid. If earcon 1 is embedded in musical earcon 2, then a difference frequency signal can be saved (845) to be used to adjust the minimal earcon (earcon 1) into the musical earcon 2 by modifying earcon 1's spectral signature using the difference frequency signal. Then the musical earcon 2 can be emitted.

[0078] Figures 11A-11E illustrate various spectral signatures of various operational earcons, where the temporal length has not been specified, in accordance with at least one exemplary embodiment. Operational earcons can vary in spectral signature and temporal length. Figures 11A-11E illustrate several non-limiting examples of various operational earcons and their respective spectral signatures. Note that no temporal length has been specified and the earcons can last anywhere from a fraction of a second to several seconds. Note also that the examples listed are not intended to be limitative of the various operational status or functions that can be represented by operational earcons.

[0079] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all modifications, equivalent structures and functions of the relevant exemplary embodiments. Thus, the

description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the exemplary embodiments of the present invention. Such variations are not to be regarded as a departure from the spirit and scope of the present invention.

CLAIMS

What is claimed is:

1. A method of communicating an earpiece status, the method comprising:

emitting an earcon, where the earcon has at least one embedded portion, where the at least one embedded portion includes at least one of a sealing quality earcon, a ear health earcon, and an ear canal transfer function earcon;

measuring a return earcon;

breaking the return earcon into return portions, where the return portions are broken into at least one of a sealing quality portion, an ear health portion, and an ear canal transfer function portion;

comparing the return portions with reference portion values; and

sending a notification signal if there are differences between the return portions and the reference portion values outside of a threshold value.

2. The method of claim 1, comprising:

monitoring ear canal sound pressure levels using an Ear Canal Microphone;

monitoring for sound leakage from an Ear Canal Receiver (ECR) loudspeaker using an Ambient Sound Microphone; and

detecting sound components correlated with earcon signals radiated by the ECR.

3. The method of claim 1, wherein the earcon is embedded within a musical signal in accordance with temporal masking principles to minimize perception of the earcon.

4. The method of claim 1, wherein the earcon includes embedded TEOAE test stimuli based on principles of temporal backward masking to reduce a perceptual loudness of the TEOAE test stimulus.

5. The method of claim 1, further comprising invoking an audiogram test if an earcon measurement indicates abnormal user auditory health.

6. The method of claim 1, wherein the earcon includes portions for an initial time segment for background noise assessment, a swept sine wave segment for measuring an Ear Canal Transfer Function (ECTF), a segment of clicks to measure otoacoustic emission acoustic responses, and a section of alternating tones for measuring ear seal integrity.

7. A method for indicating operational status of an earpiece, the method comprising the steps of:

reproducing operational audio content with an Ear Canal Receiver (ECR) housed in the earpiece;

analyzing signals from an ear canal microphone (ECM) of the earpiece responsive to the reproducing;

generating at least one acoustic indication features from the signals analyzed; outputting an indicator representing the state of the at least one acoustic indication features; and

detecting an operational status of the earpiece by in view of the indicator, where the acoustic indication feature comprises one among an ear health profile, an earphone device acoustical fitting status, and an ear seal integrity.

8. The method of claim 7, further comprising estimating a background noise level within the ear canal during the step of analyzing and estimate; and

suppressing a contribution of the background noise level from the acoustic indication feature.

9. The method of claim 7, wherein the related operational audio content is a music signal with embedded otoacoustic emission acoustic test signals.

10. The method of claim 7, wherein the operational status comprises at least one among a remaining battery power, a remaining processing power, and a remaining memory storage space for the earpiece or a paired communication device.

11. The method of claim 7, comprising scheduling the reproducing of the operational audio content upon detecting an insertion of the earpiece in an ear canal, and intermittently performing an ear seal test to monitor the integrity of the insertion.

12. The method of claim 7, wherein the operational audio content is an earcon with temporal portions devoted to various diagnostics and operational indications.

13. The method of claim 6, wherein the earcon includes a temporal portion for background noise assessment.

14. The method of claim 13, wherein the earcon includes a swept sine wave segment for measuring an Ear Canal Transfer Function (ECTF).

15. The method of claim 13, wherein the earcon includes a section of clicks to measure otoacoustic emission acoustic responses.

16. The method of claim 13, wherein the earcon includes a section of alternating tones for measuring ear seal integrity.

17. The method of claim 7, comprising monitoring changes in sound pressure level across a frequency spectrum with respect to a predetermined ear sealing profile to determine if a sealing of the earpiece is compromised.

18. A method for determining an operational status of an earpiece, the method comprising the steps of:

generating and emitting an earcon to an ear canal of a user wearing an inserted earpiece;

analyzing signals measured at an ear canal microphone (ECM) of the earpiece within the ear canal responsive to the earcon; and

determining the operational status in view of the signals analyzed that identifies a remaining battery power.

19. The method of claim 18, wherein the step of analyzing identifies at least one among a Sealing Quality Earcon (SQE), an Ear Health Earcon (EHE), and an Ear Canal Transfer Function (ECTF).

20. The method of claim 18, wherein the step of analyzing determines a Frequency Difference (FD) portion between a musical score and the earcon.

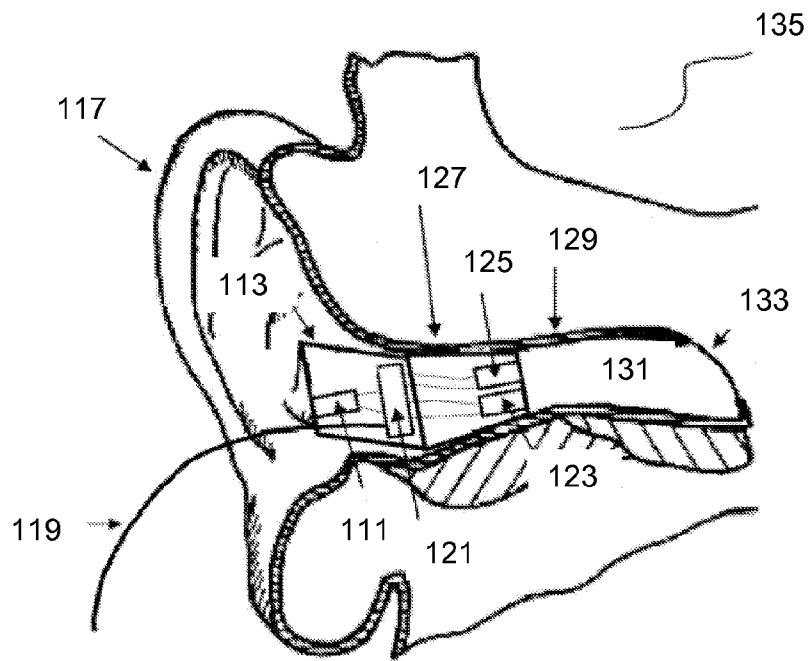
21. The method of claim 18, comprising measuring an ambient acoustic signal (AAS) and an ear canal acoustic signal (EAS) to validate that the earpiece is inserted before proceeding with the step of generating and emitting the earcon.

22. The method of claim 18, comprising measuring a noise reduction rating of the earpiece for determining the operational status.

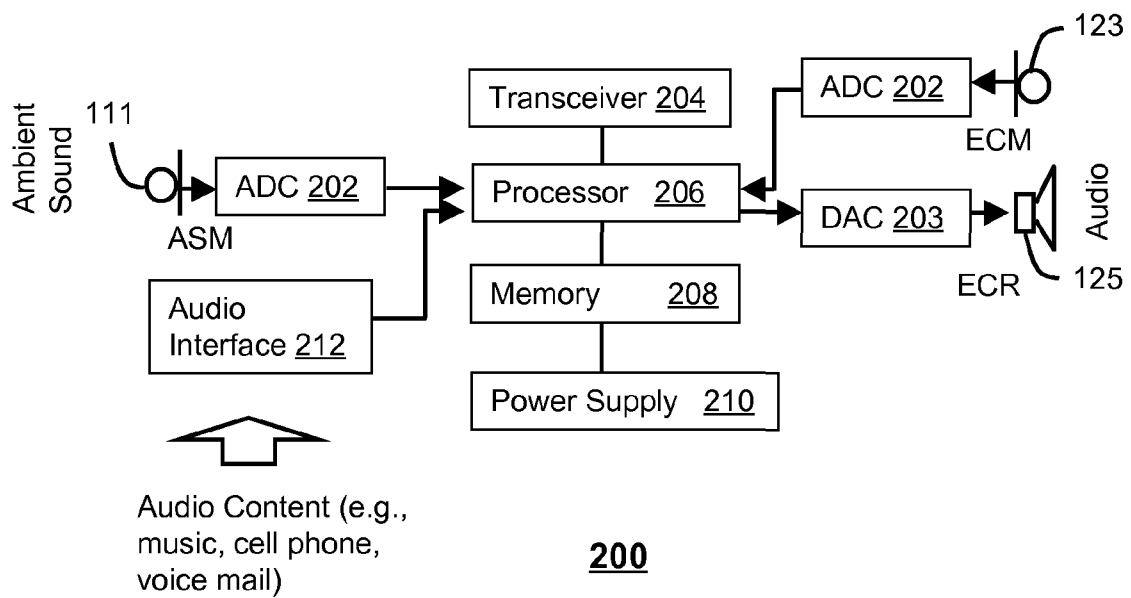
23. The method of claim 18, comprising temporally splitting the earcon into temporally separate and distinct portions, and performing an analysis on the separate distinct portions to determine if differences with predetermined mapping of the separate and distinct portions are within respective tolerances, wherein the tolerances are frequency specific for the separate distinct portions.

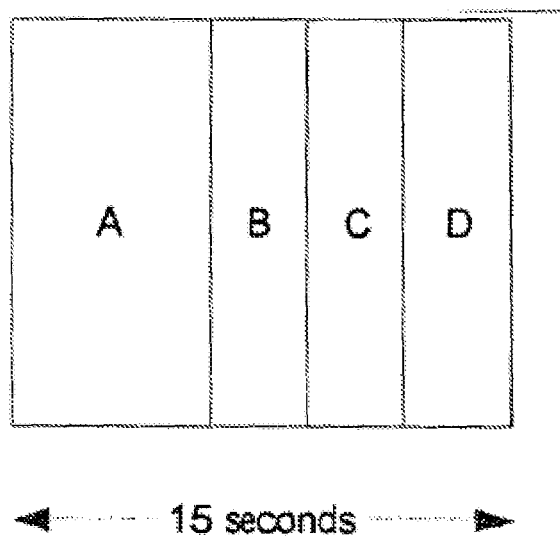
24. The method of claim 18, wherein the operational status identifies at least one among a signal noise measurement function, an Ambient Sound Microphone (ASM) sensitivity, and an Ear Canal Receiver (ECR) sensitivity.

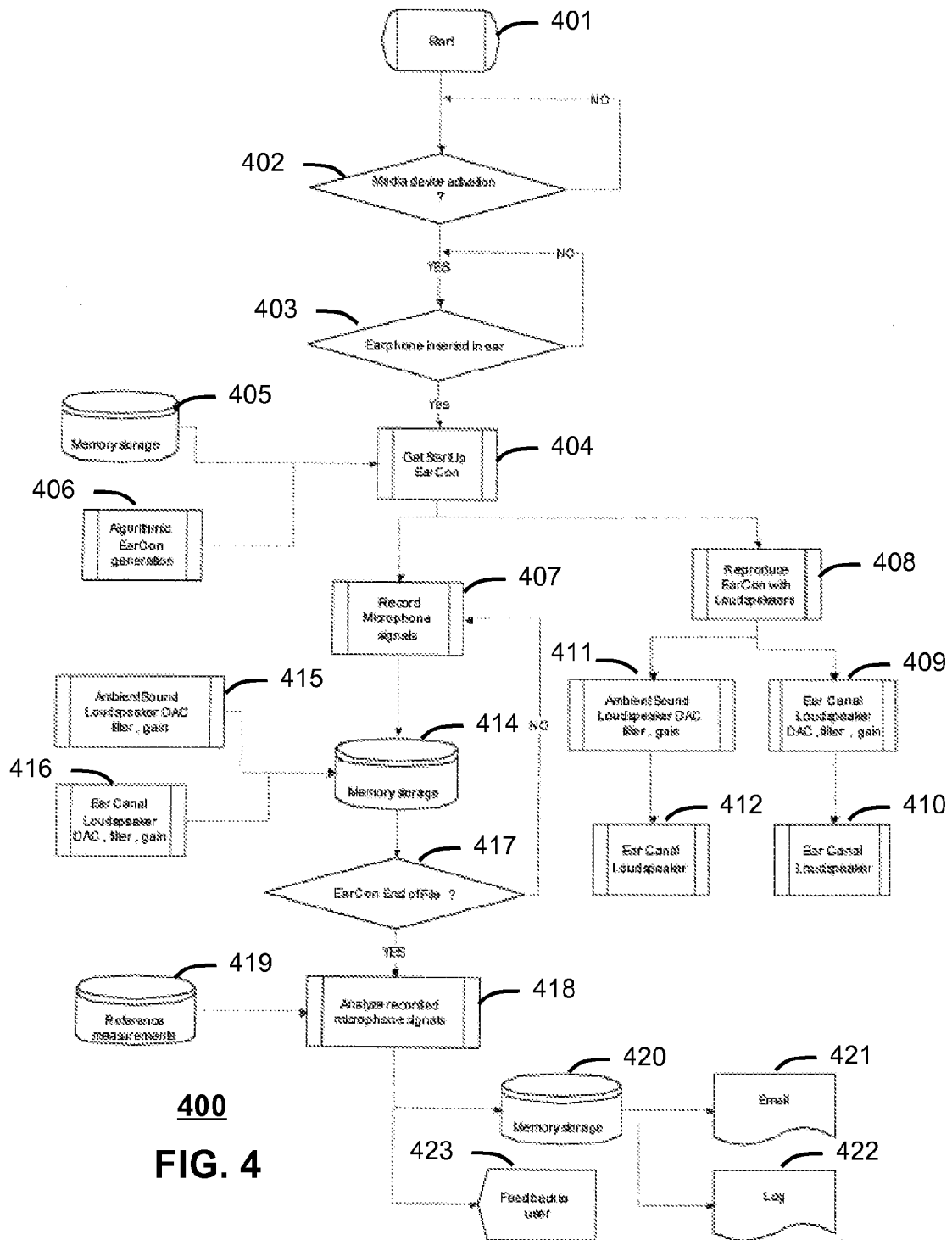
25. The method of claim 18, further comprising outputting an indicator representing by generating a visual message on a portable communication device indicating the operational status of at least one acoustic indication feature, generating an email communication and sending it to the user to indicate the operational status of the at least one acoustic indication feature, generating an electronic communication and sending it to a database storage server.



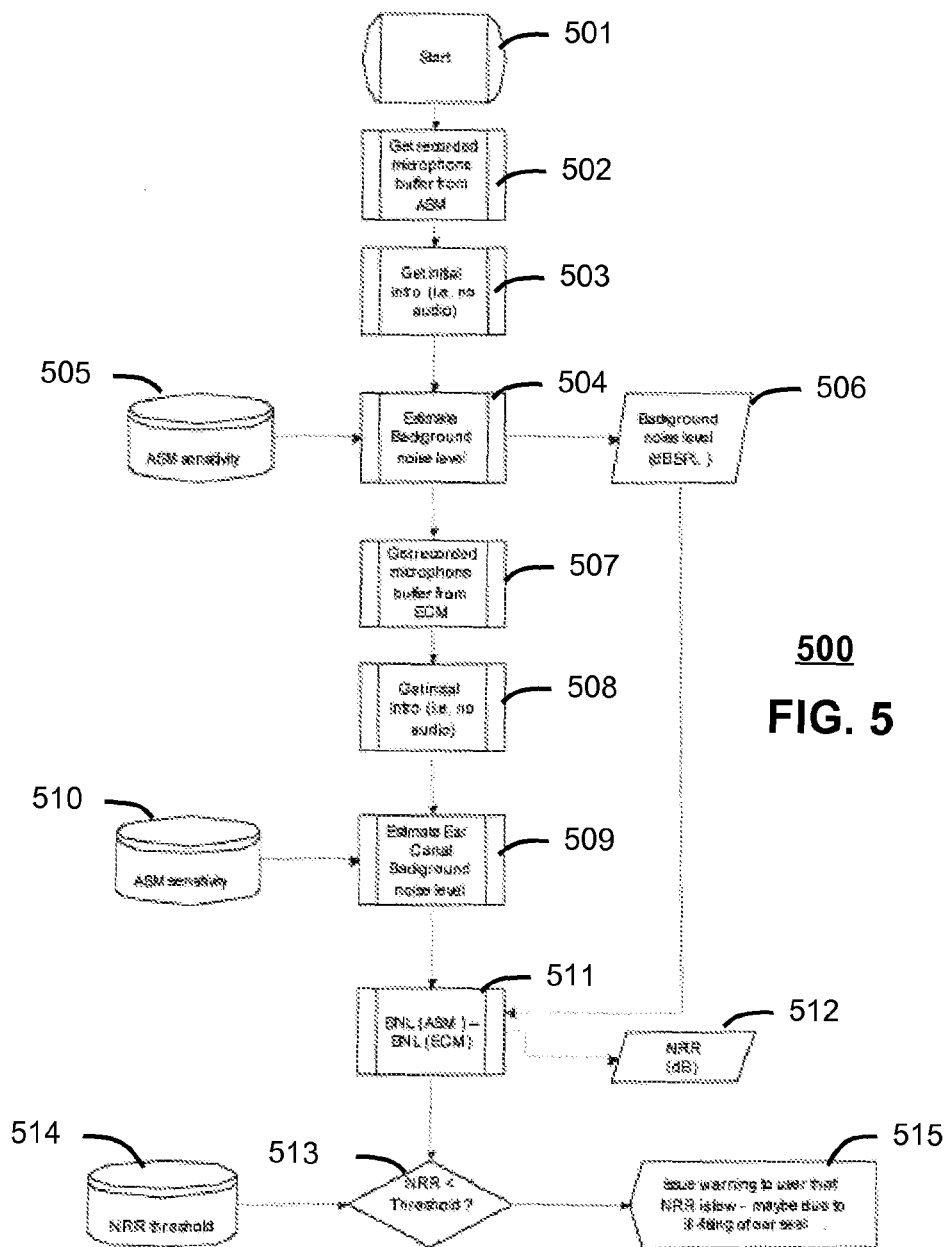
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FIG. 1

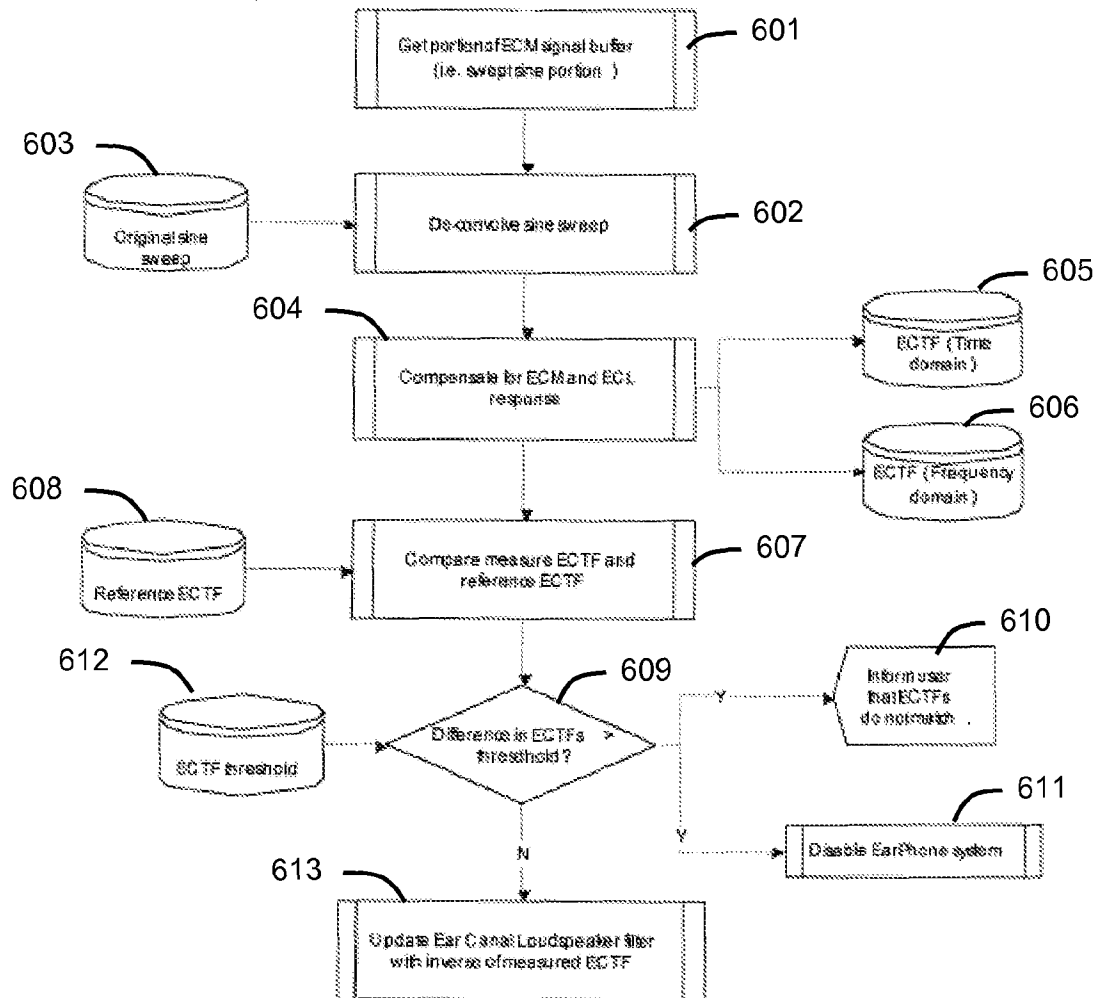


300**FIG. 3**



400
FIG. 4





600

FIG. 6

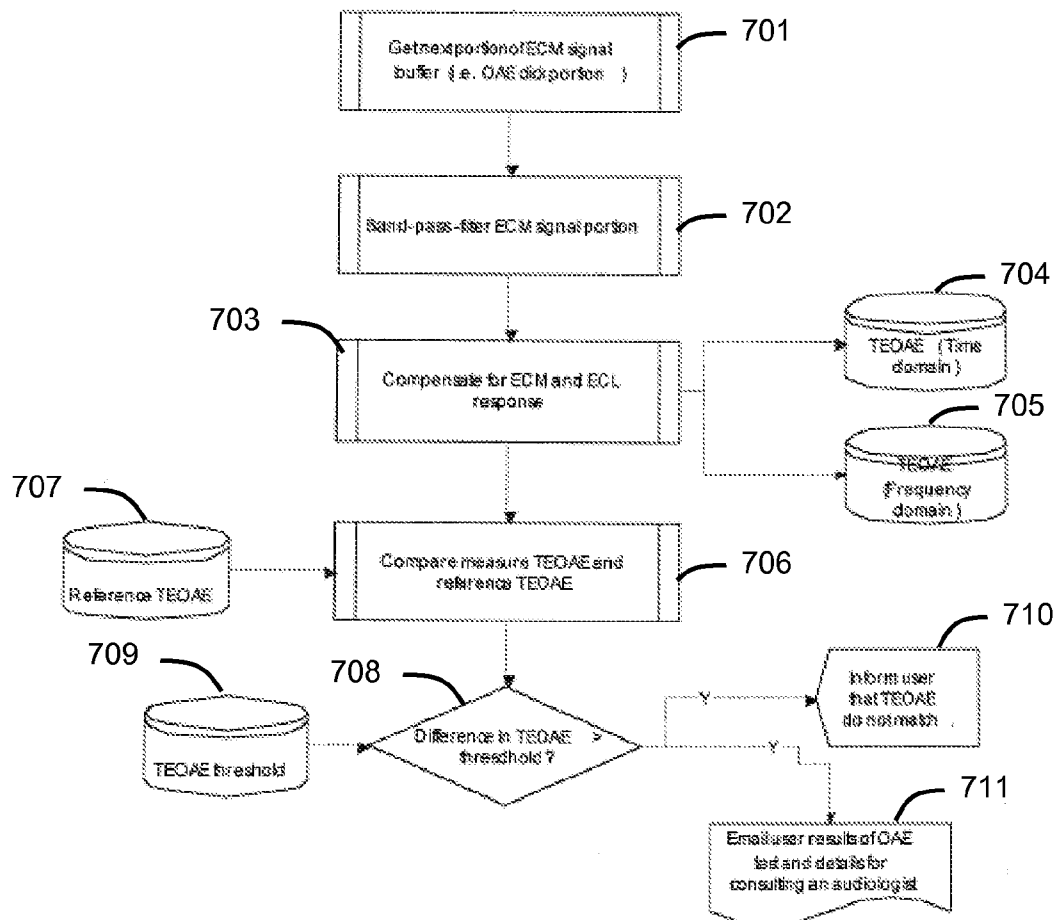
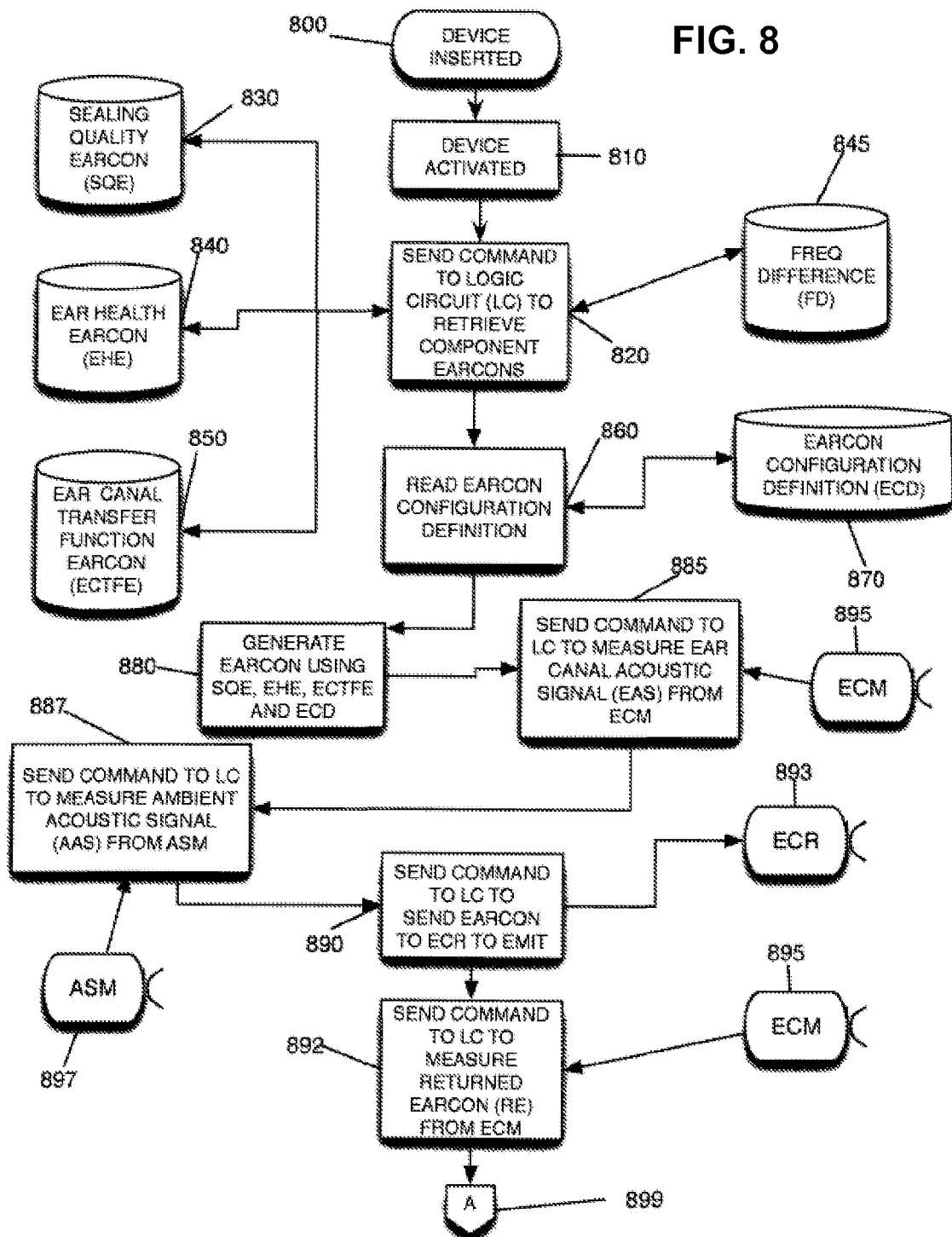
**700****FIG. 7**

FIG. 8



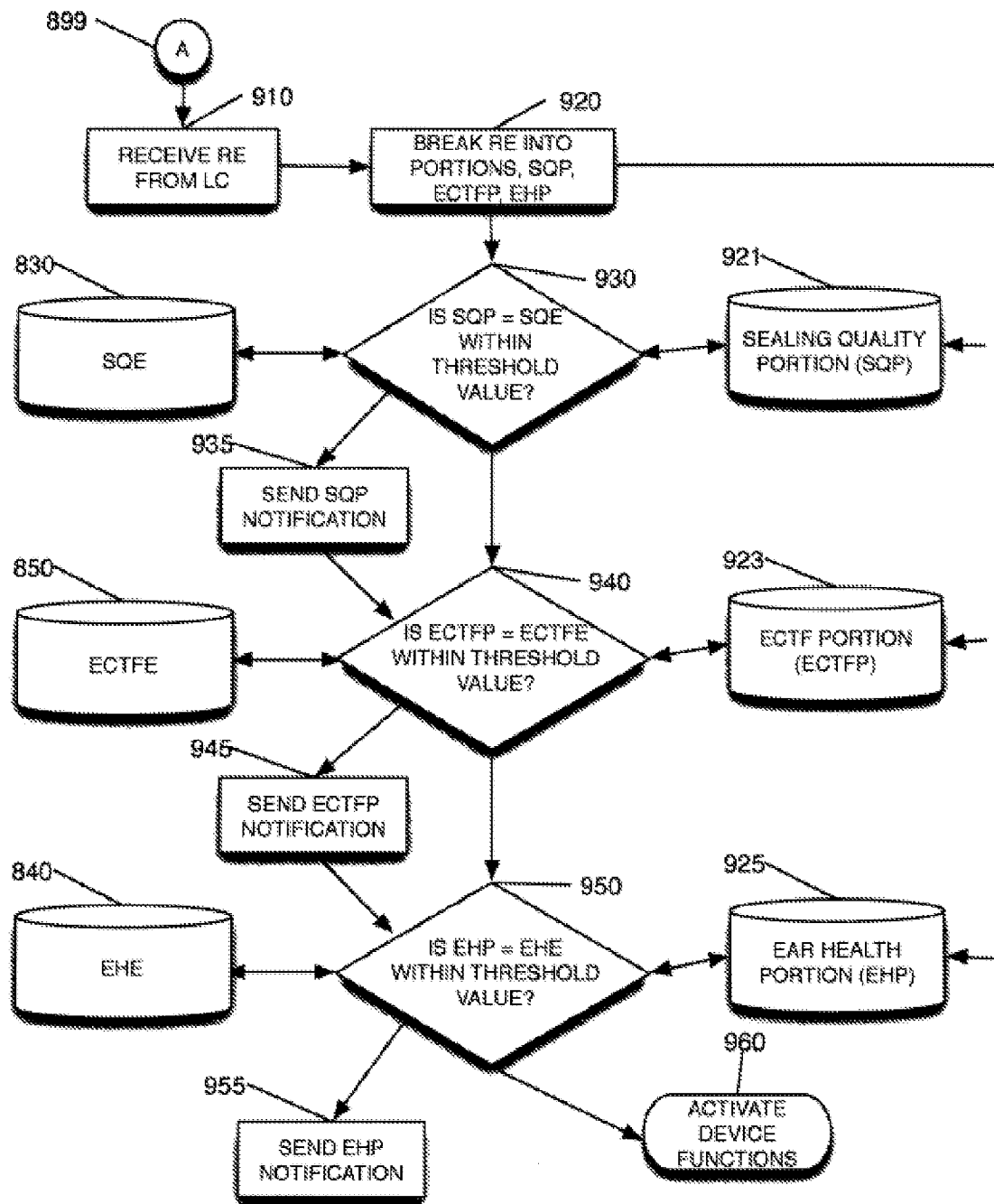
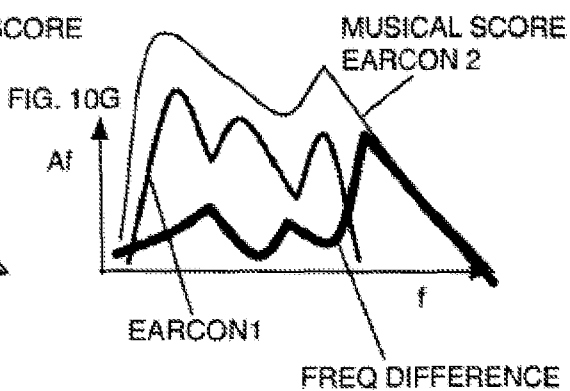
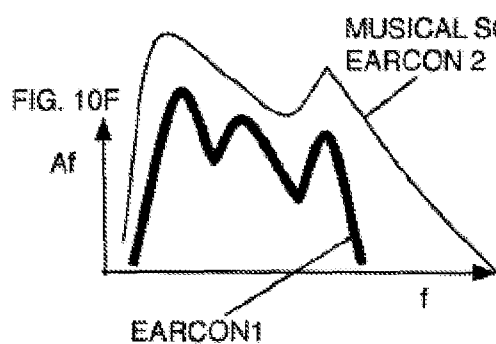
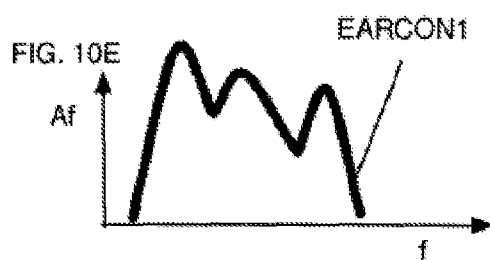
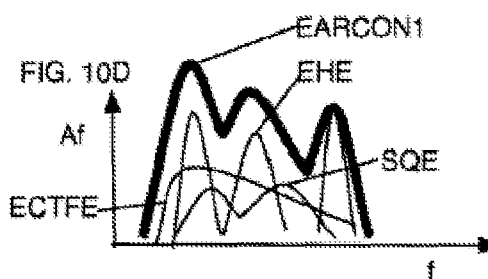
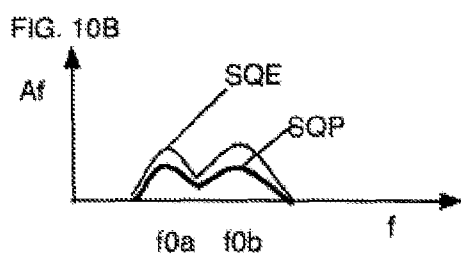
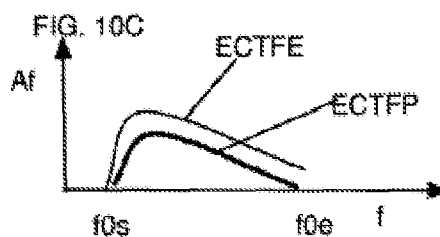
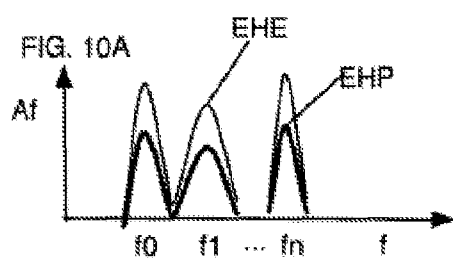
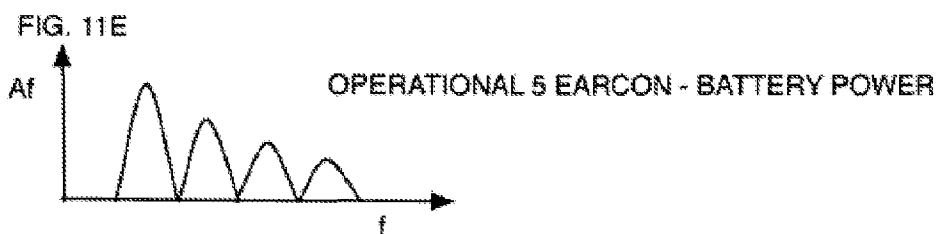
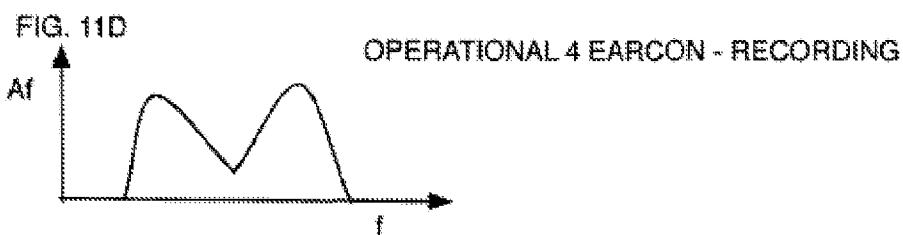
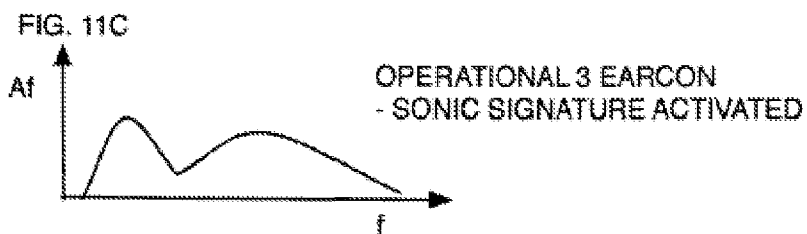
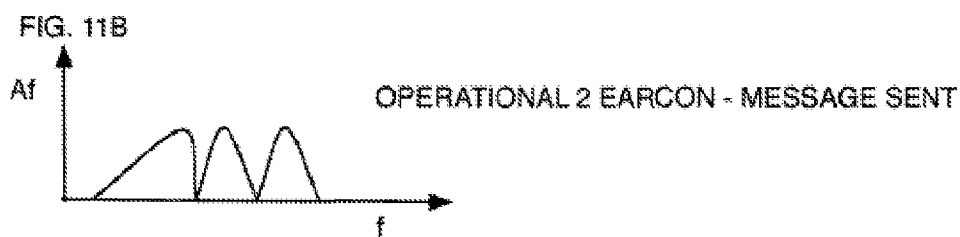
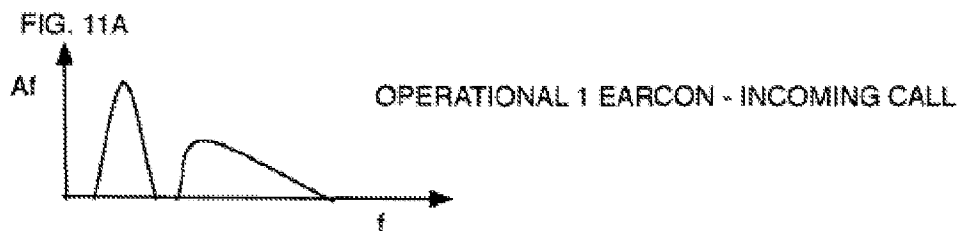


FIG. 9





INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 08/72800

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - G06G 7/48 (2008.04) USPC - 703/11 According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC(8): G06G 7/48 (2008.04) USPC: 703/11 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched IPC(8): G06G 7/48 (2008.04) (text search) USPC: 703/6, 9, 11 (text search) Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PubWEST(USPT,PGPB,EPAB,JPAB); Internet search via Google Web and Google Scholar search engines. Search Terms Used: otoacoustic OAE otoreflectance DPOAE EOAE SOAE TEOAE TrOAE earcon ear earcanal canal signal tone music hearing test user patient subject auditory health earcon ear canal frequency amplitude click floor noise				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
X	US 2006/0074341 A1 (CAUSEVIC et al.) 06 April 2006 (06.04.2006) para [0003] through [0065], Fig. 1-8	1-25		
A	US 5,885,225 A (KEEFE et al.) 23 March 1999 (23.03.1999)	1-25		
A	US 6,852,084 B1 (BOESEN) 08 February 2005 (08.02.2005)	1-25		
☐ Further documents are listed in the continuation of Box C.				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top; border: none;"> * Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; vertical-align: top; border: none;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family </td> </tr> </table>			* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
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Date of the actual completion of the international search 07 October 2008 (07.10.2008)		Date of mailing of the international search report 22 OCT 2008		
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201		Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774		

Form PCT/ISA/210 (second sheet) (April 2007)